It will be worth while, therefore, in these notes to give the salient features of the Bjerknes papers.[4]

The Bjerknes Lines of Discontinuity.—The changes of weather which are associated with the passage of HIGHS and LOWS in the temperate zone are found to depend largely upon a line of discontinuity which marks the boundary between polar and equatorial air. In an individual cyclone, this line of discontinuity consists of the steering line and the squall- or wind-shift, line. Considering as large a portion of the northern hemisphere as possible, this line of discontinuity can be traced from one storm to another so that there is little doubt that it is continuous around the world. North of this line the air is that which "has a low temperature for the latitude, shows great dryness, distinguishes itself by great visibility, and has a prevailing motion from east and north. On the southern side of the line, the tropical origin of the air is recognized by the corresponding signs—its generally higher temperature, its greater humidity, its haziness and its prevailing motion from west and south." This line is called the *polar-front line.*

Sometimes the undulations of the line are such as to cause loops which may represent the cutting off from the parent mass, masses of warm or cold air depending upon how far north or south the tropical or polar air may extend. If the warm air is cut off, the cyclone decreases in intensity and disappears; or, in the case of a new outbreak of polar air a new front is formed behind a too far advanced one; isolated masses of polar air are formed at lower latitudes. This is the formation of great anticyclones, which bring good weather.

[4] Bjerknes, J., "On the Structure of Moving Cyclones," *Monthly Weather Review*, February, 1919, pp. 95–99; "The Structure of the Atmosphere when Rain is Falling" (abstract), *ibid.*, July, 1920, p. 401; Bjerknes, V., "The Meteorology of the Temperate Zone and the General Atmospheric Circulation," *ibid.*, January, 1921, pp. 1–3; appeared also in *Nature* (London), June 24, 1920, pp. 522–524.

In the case of the individual cyclone, the phenomena along this line of discontinuity are about as follows: That part of the line which lies in a general easterly direction from the center of the cyclone is known as the *steering-line.* South of it the air is moving from the south; north of it the air is from the east. Along the line the warm southerly air rises over the denser easterly air. Passing through the center of the cyclone the line extends off in a southwesterly direction and forms the western boundary of the warm tongue of southerly air, and the eastern front of an advancing wedge of cooler northwesterly air. This line is known as the *squall line,* and its passage is frequently accompanied by considerable violence, with thunderstorms and sometimes tornadoes, but usually with only a strong blow, a rise of pressure, a drop of temperature, and, of course, a change of wind direction.

It was on the basis of the advance of these lines of discontinuity that Mr. Andrus was able to predict the path and advise the balloonists to make as little westerly progress as possible during the first night, to stay as far east and north as possible, even if it were necessary to disregard the usual practise in ballooning of staying as low as possible to avoid expenditure of ballast early in the race. The winner followed this advice and had landed in Vermont many hours before the others who had reached no greater distance than Illinois and lower Michigan. This fact demonstrates very clearly that, as Mr. Upson frankly confesses and as Mr. Andrus emphatically states, it was meteorology that won the race.

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SPECIAL ARTICLES

THE CATALYTIC PROPERTIES OF THE RESPIRATORY METALS[1]

The more important physical and chemical properties of the respiratory metals—iron, copper, manganese and vanadium—have long

[1] Contributions from the Bermuda Biological Station for Research, No. 123.

been known. Hitherto, however, the evident points of similarity which these metals possess have not been offered to explain their singular activity in respiration.

In the first place, as Griffiths[2] has pointed out, the atomic weights of these metals differ very slightly from one another: Mn = 55; Cu = 53; Fe = 55.9; V = 51.[3] Is such a condition purely accidental, or does it indicate something concerning the chemical affinities of the proteins with which these metals are associated? It should be noted also that the valences of the elements in question are variable to an unusual degree (Cu, 1–2; Mn, 2–7; Fe, 2–3; V, 3–5). So marked a degree of variation may be without theoretical significance, yet it is an interesting coincidence. These metals also closely approximate one another in specific gravity. In addition they all form oxides with great facility. But perhaps the most suggestive property which they have in common is that of catalysis.

It is a commonplace of inorganic chemistry that minute amounts of iron and of manganese hasten many reactions. This is likewise true of both copper and vanadium. But it is much more significant that these same elements also have a very profound catalytic effect upon many physiological processes. One part of manganese in one million greatly accelerates the growth rate of Aspergillus niger.[4] Moreover, the salts of copper, iron and manganese serve as powerful catalaysers for peroxides, and will in some cases replace the enzyme peroxidase. Bertrand[5] believed that his enzyme "laccase" owed its activity to manganese, but it was subsequently shown by Bach[6] that iron could take the place of manganese without altering the activity of "laccase."[7] This latter fact serves as a striking parallel to the replacement of iron by copper and manganese in certain of the respiratory pigments. But this parallel may be pushed still further. When acting upon peroxides, these metals are serving in the capacity of catalysts. Now, it is not wholly impossible that the respiratory metals serve in the same way.

Alsberg and Clark[8] believe that the copper of hæmocyanin acts as a catalyst for oxygen, and if this be the case, the oxygen would be more readily given off to such acceptors as are present in the tissues, thus making hæmocyanin in reality analogous to a peroxide-peroxidase system. As for vanadium, Hecht[9] holds (on the grounds of the relatively low binding power for oxygen which Winterstein[10] reports for ascidian blood) that vanadium, too, probably serves the *rôle* of catalyst in the blood of tunicates. Also, from the description which Griffiths[11] gives of his pinnaglobin,[12] it is not at all impossible that the manganese of this pigment serves in a similar capacity. The fact that the metals are always present in very small quantities further strengthens the catalyst hypothesis. Hæmocyanin, which has a molecular weight of 18.762 (Griffiths), has in its molecule only 63.6 gram molecules of copper. Furthermore, one should recall that in certain sluggish animals respiratory pigments are present which are not associated with any oxidizing metals. These have been investigated extensively by Griffiths,[13] and are called by him achroglobins. An α-achroglobin is found in a limpet, *Patella vulgata*, and a β-achroglobin in chitons. A γ-achroblobin was described for

2 "Respiratory Proteids," London, 1877, p. 60.

3 Since Griffith's work, vanadium has been described by Henze (1911–12, *Zeits. physiol. Chem.*, 72, 494; 79, 215) for the blood of ascidians. The writer includes it, therefore, with the list of Griffiths.

4 Bertrand, C. R., Acad. Sci., Paris, 1912, 154, 381.

5 C. R. Acad. Sci., Paris, 1897, 124, 1032.

6 *Chem. Berichte*, 1910, 43, 364.

7 Bayliss, "Principles of Gen. Physiol.," 1918, London, p. 585.

8 *Jour. Biol. Chem.*, 1914, 19, 503.

9 *Amer. Jour. Physiol.*, 1918, 40, 165.

10 *Biochem. Zeits.*, 1909, 19, 384.

11 "Respiratory Proteids," London, 1897.

12 A respiratory protein containing manganese. It was first isolated from *Pinna squamosa*, from which it derives its name.

13 "Respiratory Proteids," London, 1897.

ascidians, but the presence of vanadium in association with the proteid escaped Griffith's observation. Whether non-metallic respiratory pigments represent degeneration, or whether they are phylogenetic predecessors of metallic pigments, is difficult to decide; but their presence in the animal kingdom shows that the function of oxygenation is not dependent upon the presence of a metal in the pigment molecule—a fact which gives strong indication that the association with metals was occasioned by the need of a greater capacity for ready oxidation and reduction, the need, that is, of a catalyst.

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THE INFLUENCE OF HEAT AND OXIDATION UPON THE NUTRITIVE AND ANTISCORBUTIC PROPERTIES OF COW'S MILK[1]

In a recent paper[2] from the Minnesota Experiment Station we submitted data which indicated that the nutritive and antiscorbutic properties of cow's milk are dependent upon the nature of the feeding materials which constitute the dairy ration.

In April, 1920, a series of studies was initiated with the view of ascertaining the influence of heat upon the nutritive properties and the antiscorbutic potency of milk. The experimental milk used in these studies was obtained from an Ayershire cow fed upon a ration composed of the same types of feeding materials throughout the experimental period. By this method it was hoped that we might eliminate fluctuations in the vitamine content of the dairy ration and thereby reduce to a minimum any variations in the nutritive properties of the milk.

In these studies we have used a total of 163 guinea pigs, and control groups were included in each series. In the first series of experiments it was found that boiled milk was practically equal, in nutritive properties, to the unheated raw milk. The pasteurized milk, heated at 145° F. for 30 minutes, produced scurvy very quickly and all of the animals died in a very short time. Examination revealed the fact that the pasteurized milks had been stirred rather violently with motor-driven propellors, while the boiled milk had not been stirred mechanically. This led us to believe that oxidation had occurred in the pasteurized milks due to the intimate contact of air with the milk particles. Consequently, many new animals have been added with the result that we have been able to show that the nutritive and antiscorbutic properties of cow's milk are destroyed by oxidation. Some destruction occurs when air is bubbled through milk at 145° F. for 30 minutes, but the destruction is much more marked when oxygen or hydrogen peroxide is used. Oxygen and hydrogen peroxide will destroy the antiscorbutic accessory at room temperature although the destructive action is hastened as the temperature increases. Milk may be pasteurized in closed vessels or boiled in the open air without appearing to lose its nutritive and antiscorbutic properties when fed to guinea pigs. When carbon dioxide is bubbled through the milk, it compares very favorably in nutritive properties with the raw milk.

Our work, now in progress, on orange juice shows that the antiscorbutic properties are not destroyed by boiling for 30 minutes. At least, if destruction occurs it is not discernible with the methods employed. Hydrogen peroxide destroys the antiscorbutic factor in orange juice at room temperature, and the speed of the oxidation is hastened as the temperature increases. Oxidation would appear to be a more important factor than heating as far as the nutritive and antiscorbutic properties of milk are concerned.

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2 Dutcher, R. A., Eckles, C. H., Dahle, C. D., Mead, S. W., and Schaefer, O. G., *J. Biol. Chem.*, XLV., 119–132, December, 1920.